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WIND-TUNNEL INVESTIGATION OF TRIMMING TABS ON A THICKENED AND BEVELED AILERON ON A TAPERED LOW-DRAG WING

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SUMMARY

An investigation was made in the LMAL 7- by 10-foot tunnel of three inset tabs and of one attached tab on the beveled aileron of a low-drag wing. The effects of gaps at the aileron and the tab noses were determined for the three inset tabs, and the effects of the alinement of the top cover plate on the aileron characteristics were determined with the tab sealed in the neutral position.

The results of the tests indicated that, of the arrangements tested, an inset tab with a chord 50 percent of the aileron chord provided the most satisfactory trimming characteristics on a beveled aileron. The attached tab appeared to be satisfactory as a trimming device; its addition to a beveled aileron, however, would increase the control-operating force. No appreciable change in aileron effectiveness was observed for any of the trimming-tab arrangements tested. Leakage at the aileron and the tab noses decreased the effectiveness of the tab as a trimming device, especially for tabs of small chord.

INTRODUCTION

Because of the increased importance of obtaining adequate lateral control with reasonable control forces for high-speed airplanes, the NACA has undertaken an extensive investigation of lateral-control devices. The purposes of this program are to determine the characteristics of existing lateral-control devices, to determine the effects of modifications to existing devices, and to develop new devices that show promise of being more satisfactory than those now in use.

Tests of an aileron on a low-drag wing (reference 1) indicated that thickening and beveling the trailing edge of the aileron would result in a substantial reduction of high-speed control forces. These results agreed with tests of conventional sections (references 2 and 3). Tests of small-chord tabs on two of the beveled-aileron arrangements of reference 1, however, gave unsatisfactory results. Tab effectiveness varied greatly with aileron profile and the variation of aileron hinge-moment coefficient with aileron deflection increased negatively when the tabs were deflected. An airplane with these small-chord tabs deflected would have higher wheel forces than with tabs neutral and would probably have unsymmetrical wheel-force characteristics for right and left roll.

The present tests were made to determine the effects of tabs with chords 15, 30, and 50 percent of the aileron chord on the characteristics of a beveled aileron on the tapered low-drag wing of reference 1.

APPARATUS AND METHODS

Models

The wing model, shown in figure 1, was the same as that tested in the investigation of reference 1. The test panel was a 0.40-scale partial-span model of a low-drag wing, constructed of laminated mahogany. The airfoil section varied from NACA 66,2-2(13.716) at the root to NACA 66,2-2(13.125) near the tip.

The wing was equipped with a 0.20c aileron which is shown in figures 2 to 4. The aileron cross sections are the same as for one of the ailerons of reference 1, but the tip shape and the hinge location have been changed. The true trailing-edge profile for this low-drag wing is a cusp. In forming the beveled contour, the original aileron was thickened linearly and symmetrically from the nose arc to the trailing edge and the thickness of the trailing edge was increased by 2 percent of the wing chord. A portion of the trailing edge, 30 percent of the aileron chord, was linearly beveled to the original trailing-edge thickness and the juncture between the bevel and the aileron was rounded with a radius equal to 20 percent of the wing chord. For some of the tests the aileron was sealed by a rubber dam that prevented leakage at the aileron nose but did not seal the 0.02-inch longitudinal gaps at the ends of the aileron.

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The 0.20c aileron was tested with three inset trimming tabs and with one attached metal tab. Details of the three inset tabs are shown in figures 2 to 4; of the attached tab, in figure 4. Each inset tab was constructed with a gap of 0.002c between the cover plates and the tab nose. For the sealed conditions, the gap was covered with "Scotch" cellulose tape.

The alinement of the top cover plate was altered by rotating the cover plate about its leading edge until the gap at its trailing edge was of the specified size. The position of the leading edge of the cover plate is shown in figure 2.

Geometric characteristics of the full-size low-drag wing and the 0.40-scale model of the wing and of the panel tested are presented in table I.

Test Installation

Details of the test installation are shown schematically in figure 5. The model was mounted horizontally in the LMAL 7- by 10-foot tunnel (reference 4) with the inboard end of the model adjacent to but not in contact with the wall of the tunnel, the wall thereby acting as a reflection plane. The model was supported entirely by the balance frame in order that all the forces and moments acting upon it could be measured. Provision was made for changing the angle of attack of the model while the tunnel was in operation.

The aileron was manually deflected through a calibrated torque rod and linkage system and the hinge moments were determined from the twist of the rod as described in reference 1.

Test Conditions

All tests were made at a dynamic pressure of 16.37 pounds per square foot, which corresponds to a velocity of approximately 80 miles per hour. The test Reynolds number, based on the mean chord of a complete 0.40-scale model (3.21 ft), was about 2,350,000. The effective Reynolds number of the tests was about 3,760,000 because of the turbulence factor of 1.6 for the LMAL 7- by 10-foot tunnel. The present tests were made at low scale, low velocity, and high turbulence relative to the flight conditions to which the results will generally be applied. In the present investigation the effects of these variables were not determined or estimated, but some work toward their determination is now in progress. Subsequent tests (as yet unpublished) of a similar aileron arrangement on a modern fighter airplane, incidentally, gave results essentially in agreement with the results presented herein.

RESULTS AND DISCUSSION

Coefficients and Corrections

The symbols used in the presentation of the results are:

C_L lift coefficient (L/qS')

C_D drag coefficient (D/qS')

C_l' rolling-moment coefficient (L'/qbS)

C_h aileron hinge-moment coefficient $(H/qS_a\bar{c}_a)$

L twice lift of test panel

D twice drag of test panel

L' rolling moment about wind axis in plane of symmetry of complete wing due to aileron deflection

H aileron hinge moment

c wing chord

c_a aileron chord rearward of hinge axis (measured perpendicular to hinge axis)

$\bar{c}_a$ root-mean-square chord of aileron (measured perpendicular to hinge axis)

b span of complete wing

S area of complete wing

S' twice area of test panel

S_a area of one aileron rearward of hinge axis

α angle of attack of wing

δ_a aileron deflection from neutral; positive when trailing edge is down

δ_t tab deflection relative to aileron; positive when trailing edge is down

q dynamic pressure of air stream, uncorrected for blocking $(\frac{1}{2}\rho V^2)$

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A positive value of L' or C_l' corresponds to an increase in lift of the model. The angle of attack, the drag coefficient, and the rolling-moment coefficient have been corrected for the effects of the jet boundaries and to the aspect ratio and the taper ratio of the complete wing as was done in reference 1. The hinge-moment correction was estimated to be small and was not applied. None of the results were corrected for the effects of the support strut, the gap between the model and the wall, leakage through the wall around the support tube, and the boundary layer at the wall.

Effects of Alinement of Top Cover Plate

The effect of the alinement of the top cover plate on the lift, the drag, and the hinge-moment coefficients of the model with aileron neutral is shown in figure 6; on the rolling- and the hinge-moment coefficients with aileron deflected, in figure 7. Although the variation of the cover-plate alinement has a fairly large effect upon the aileron hinge-moment coefficient at aileron deflections between -4° and 12°, the effect is small outside of this range and may even reverse. An outward deflection of the cover plate - that is, an increase of the gap - resulted in a considerable loss of rolling-moment effectiveness of the downgoing aileron. The effects of varying the alinement of the top cover plate were greater for the unsealed than for the sealed aileron, but, in neither condition, does variation of cover-plate alinement appear to offer a very promising means of trimming.

In agreement with the results of reference 1, the present tests showed that a gap at the aileron hinge reduced appreciably the rolling-moment effectiveness of the aileron and tended to cause overbalance at small deflections. The marked changes in hinge moments resulting from the effect of a small gap indicate the necessity for careful detail design in any practical application of this type of aileron. Attention is also called to the discontinuity in hinge moments at angles of attack between 0° and 2°, as shown on the curves of C_h against α.

Tab Characteristics

Rolling-moment data are not presented because deflection of the tabs had no appreciable effect on the increment of rolling-moment coefficient that resulted from a given aileron deflection. During all the tab tests, the alinement of the top cover plate was adjusted to give a gap of 0.002c; the lift, the drag, and the rolling-moment characteristics of the model with tabs sealed in the neutral position were as given in figures 6 and 7. Unsealing the tabs had no practical effect on these characteristics. When the tabs were deflected, the resulting curves of rolling-moment coefficient against aileron deflection were raised or lowered relative to the tab-neutral curve by approximately the amount indicated in the following table:

Tab	$\partial C_l'/\partial \delta_t$
$0.15c_a$ by $0.30b_a$	0.00008
$0.30c_a$ by $0.20b_a$	.00010
$0.50c_a$ by $0.20b_a$	.00012

The $0.15c_a$ by $0.30b_a$ tab.- The hinge-moment characteristics of the aileron with the $0.15c_a$ tab (fig. 2) are shown in figures 8 to 11. With the tab and the aileron gaps sealed (fig. 8), the increments of C_h due to tab deflection are reasonably constant at high angle of attack but not at low angle of attack. The increments of C_h, at $\alpha = 1.0^{\circ}$, generally are a minimum near the neutral position of the aileron, which is the region of most importance for trimming. With the tab deflected, moreover, the variation of aileron hinge-moment coefficient with aileron deflection becomes more negative, a change that would increase the control forces. Because the gaps at the aileron and the tab noses were found to emphasize these objectionable characteristics, complete hinge-moment data were not obtained for the other gap conditions (figs. 9 to 11). The $0.15c_a$ tab is considered unsatisfactory as a trimming device but shows some promise for use as a balancing tab.

The $0.30c_a$ by $0.20b_a$ tab.- The hinge-moment characteristics of the $0.30c_a$ tab (fig. 3) are shown in figures 12 to 15. With aileron and tab gaps sealed (fig. 12), the $0.30c_a$ tab appears more suitable for trimming than the $0.15c_a$ tab with gaps sealed (fig. 8). Unsealing the gaps, particularly the tab gap, is again shown to be detrimental to the tab as a trimming device.

The hinge-moment characteristics of the aileron with tab neutral are not identical for the several inset-tab installations. Some variation might be expected when the tab gaps are unsealed, but the variations observed when the tab gaps were sealed are thought to have been the result of errors in the construction of the model or of errors in the determination of the hinge moments. In comparing tab characteristics, a comparison of the increments of C_h due to tab deflection rather than of total C_h is thought advisable.

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The $0.50c_a$ by $0.20b_a$ tab.- Of the three inset tabs tested, the $0.50c_a$ tab (fig. 4) appeared to have the best characteristics for trimming. (See figs. 16 to 19.) Although aileron and tab gaps had a detrimental effect on the tab characteristics, this effect was not so pronounced for the $0.50c_a$ tab as for the tabs with smaller chords; the $0.50c_a$ tab is thought to be acceptable for trimming with any of the gap conditions tested. Although better for trimming than the tabs with smaller chords, the $0.50c_a$ tab may not be better for balancing because it is likely to produce a greater loss of maximum rolling-moment coefficient for a given reduction of control force.

The $0.084\bar{c}_a$ by $0.126b_a$ attached tab.- The effects of a $0.084\bar{c}_a$ attached tab (fig. 4) on the hinge-moment characteristics of the aileron are presented in figure 20. This tab was effective as a trimming device and showed little tendency to change the value of $\partial C_h/\partial \delta_a$ as it was deflected. The addition of this tab to the aileron, however, increased the increment of hinge-moment coefficient between $\delta_a = 15^\circ$ and $\delta_a = -15^\circ$ by about 25 percent relative to the corresponding increment for the inset tabs.

CONCLUSIONS

The results of the tests of three inset tabs and one attached tab on the beveled aileron of a low-drag wing indicated that, for the arrangements tested, the following conclusions may be drawn:

1. Of the inset tabs tested, the tab with a chord 50 percent of the aileron chord had the best characteristics for trimming. Its characteristics were the least affected by gaps and are thought to be satisfactory for trimming with any of the gap conditions tested.

2. The attached tab appeared to be satisfactory as a trimming device; its addition to a beveled aileron, however, would increase the control-operating force.

3. No appreciable change in aileron effectiveness resulted from deflection of the tabs as trimming devices.

4. Gaps at the leading edges of the tabs or ailerons were detrimental to tab characteristics for trimming, especially for tabs of small chord.

5. The small-chord inset tabs showed promise as linked balancing tabs. Gaps did not appear to be so detrimental to the tabs for balancing as for trimming.

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2. Jones, Robert T., and Ames, Milton B., Jr.: Wind-Tunnel Investigation of Control-Surface Characteristics. V - The Use of a Beveled Trailing Edge to Reduce the Hinge Moment of a Control Surface. NACA A.R.R., March 1942.

3. Rogallo, F. M., and Purser, Paul E.: Wind-Tunnel Investigation of a Plain Aileron with Various Trailing-Edge Modifications on a Tapered Wing. II - Ailerons with Thickened and Beveled Trailing Edges. NACA A.R.R., Oct. 1942.

4. Wenzinger, Carl J., and Harris, Thomas A.: Wind-Tunnel Investigation of an N.A.C.A. 23012 Airfoil with Various Arrangements of Slotted Flaps. Rep. No. 664, NACA, 1939.

TABLE I. - GEOMETRIC CHARACTERISTICS OF LOW-DRAG WING AND OF 0.40-SCALE MODEL OF WING AND TEST PANEL

	Wing area (sq ft)	Area of test panel (sq ft)	Wing span (in.)	Root chord (in.)	Tip chord (in.)	M.A.C. (in.)	Aspect ratio
Full size	414	118.6	660	128.00	53.85	96.33	7.3
0.40-scale model	66.24	18.98	264	51.20	21.54	38.53	7.3
0.40-scale model of test panel	--------	18.98	-----	41.33	21.54	------	------

	Aileron root-mean-square chord (in.)	Area of one aileron (sq in.)	Aileron chord, inboard end (in.)	Aileron chord, outboard end (in.)	Airfoil section at station 110 (model station, 0)	Airfoil section at station 308 (model station, 79.2)
Full size	14.80	2100	17.78	11.60	NACA 66,2-2(13.716)	NACA 66,2-2(13.125)
0.40-scale model	5.92	336	7.11	4.64	NACA 66,2-2(13.716)	NACA 66,2-2(13.125)
0.40-scale model of test panel	5.92	336	7.11	4.64	NACA 66,2-2(13.716)	NACA 66,2-2(13.125)

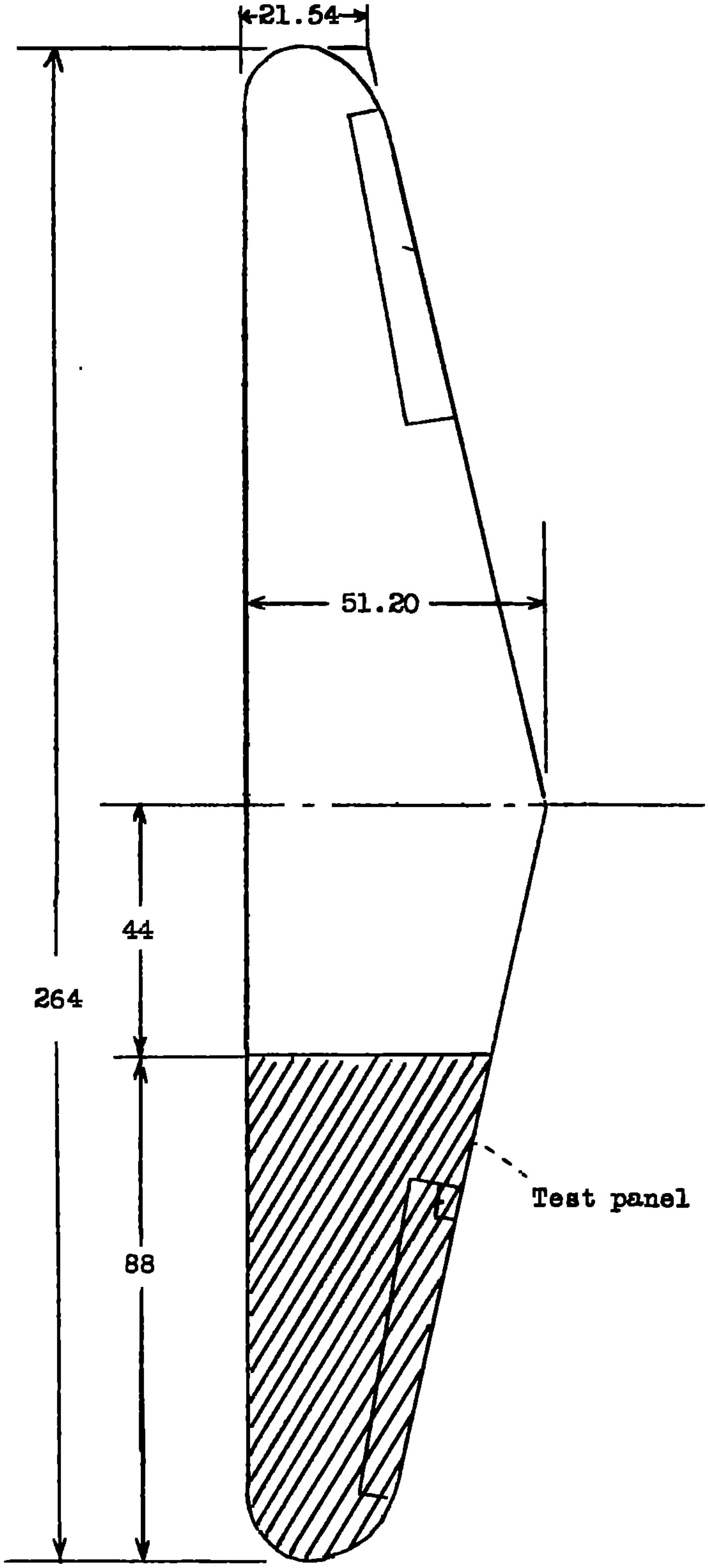

Figure 1.- Planform of 0.40-scale model of wing panel tested and of complete wing for which characteristics are given. All dimensions given in inches.

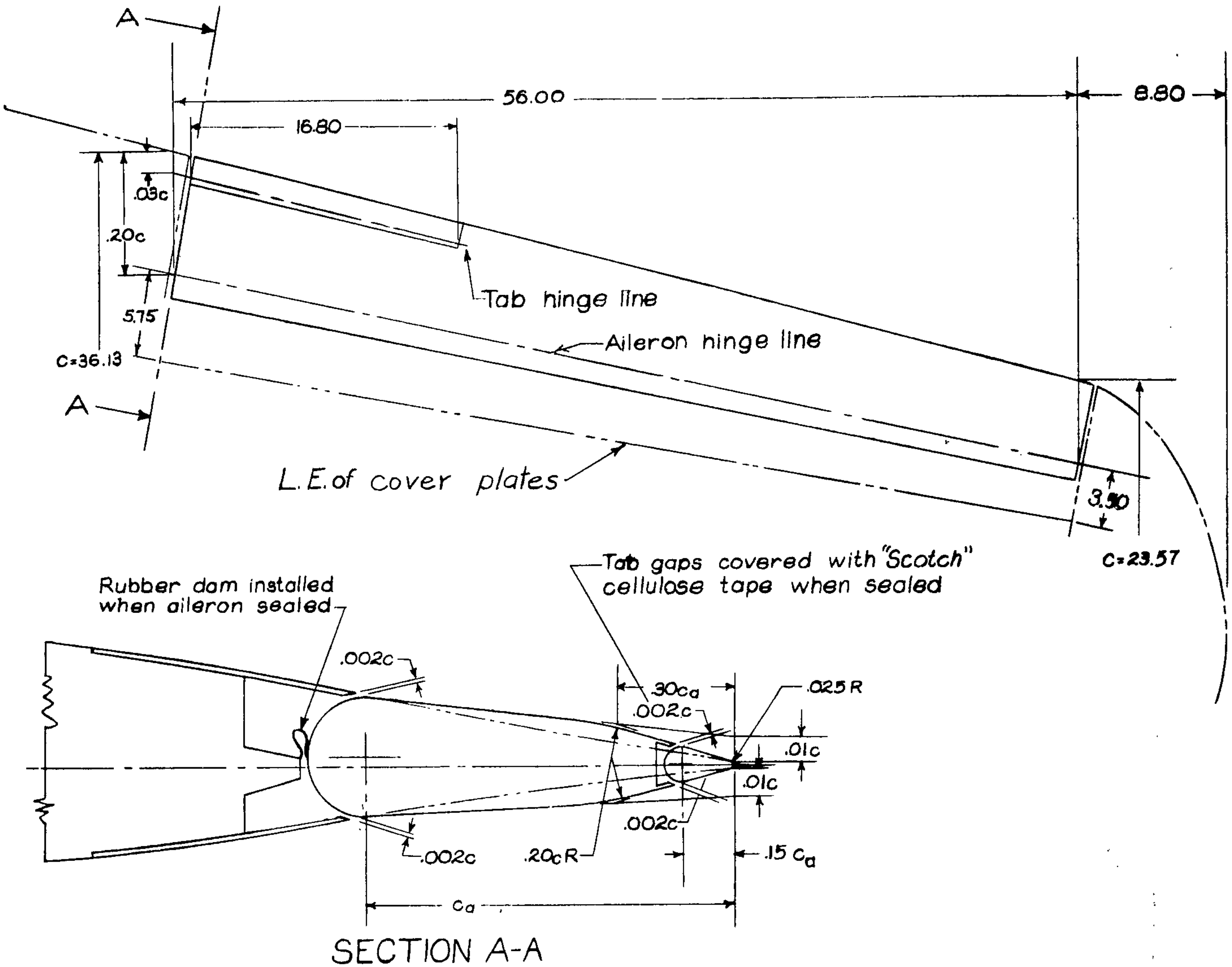

Figure 2: Beveled aileron with $0.15 c_a$ by $0.30\ b_a$ trimming tab.

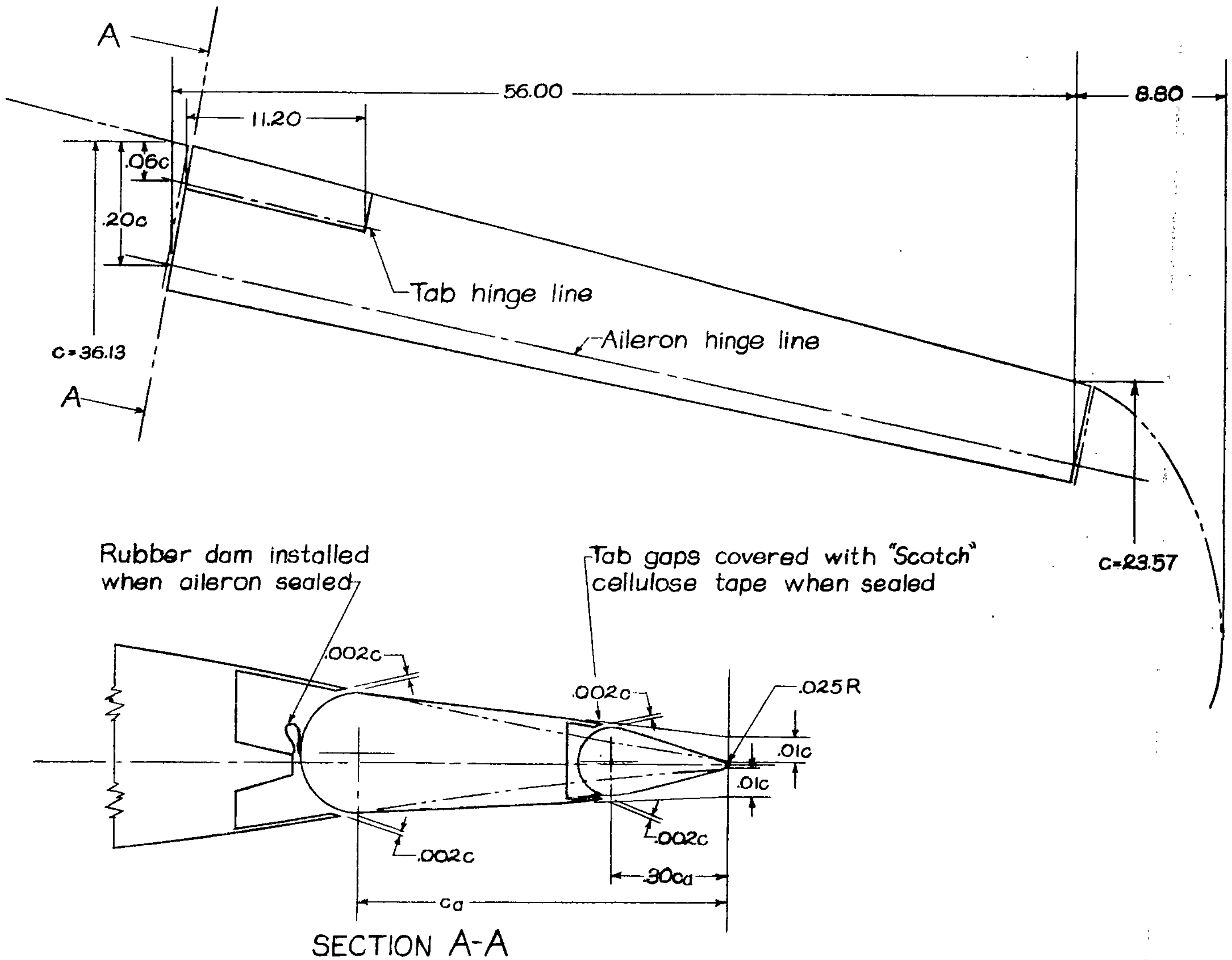

Figure 3- Beveled aileron with $0.30c_a$ by $0.20\ b_a$ trimming tab.

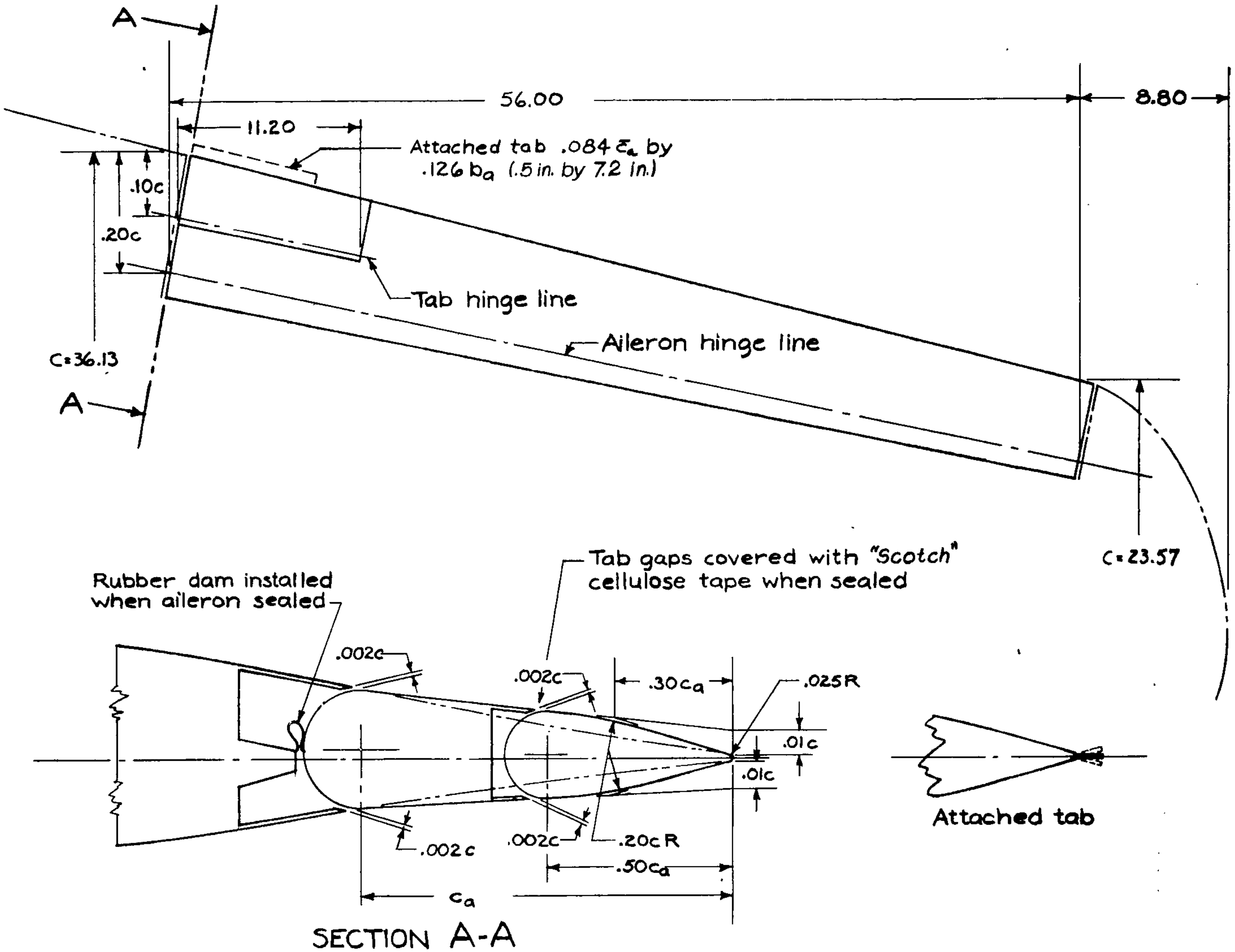

Figure 4.- Beveled aileron with 0.50c_a by 0.20 b_a trimming tab and 0.084$\bar{c}_a$ by 0.126 b_a attached tab.

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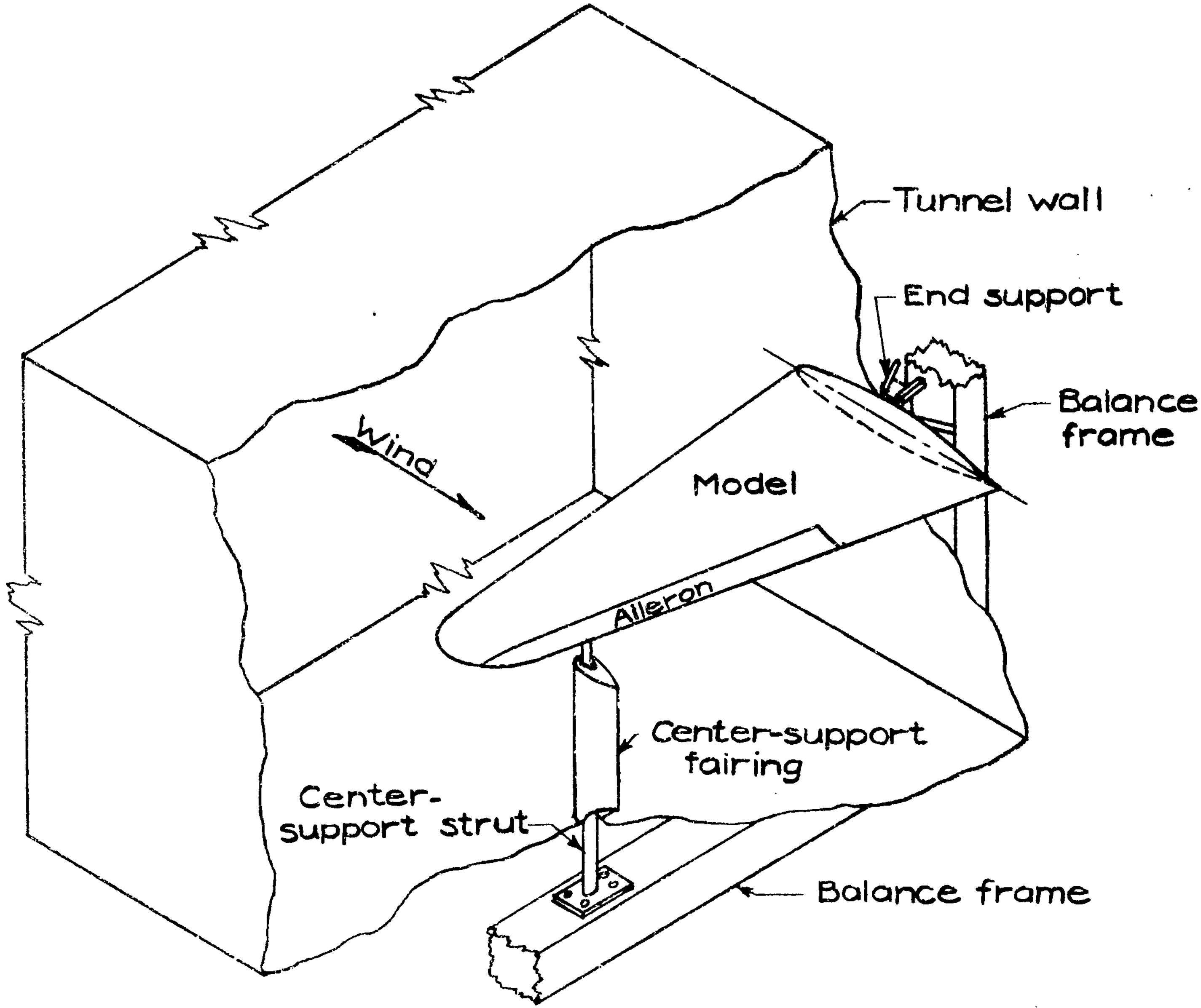
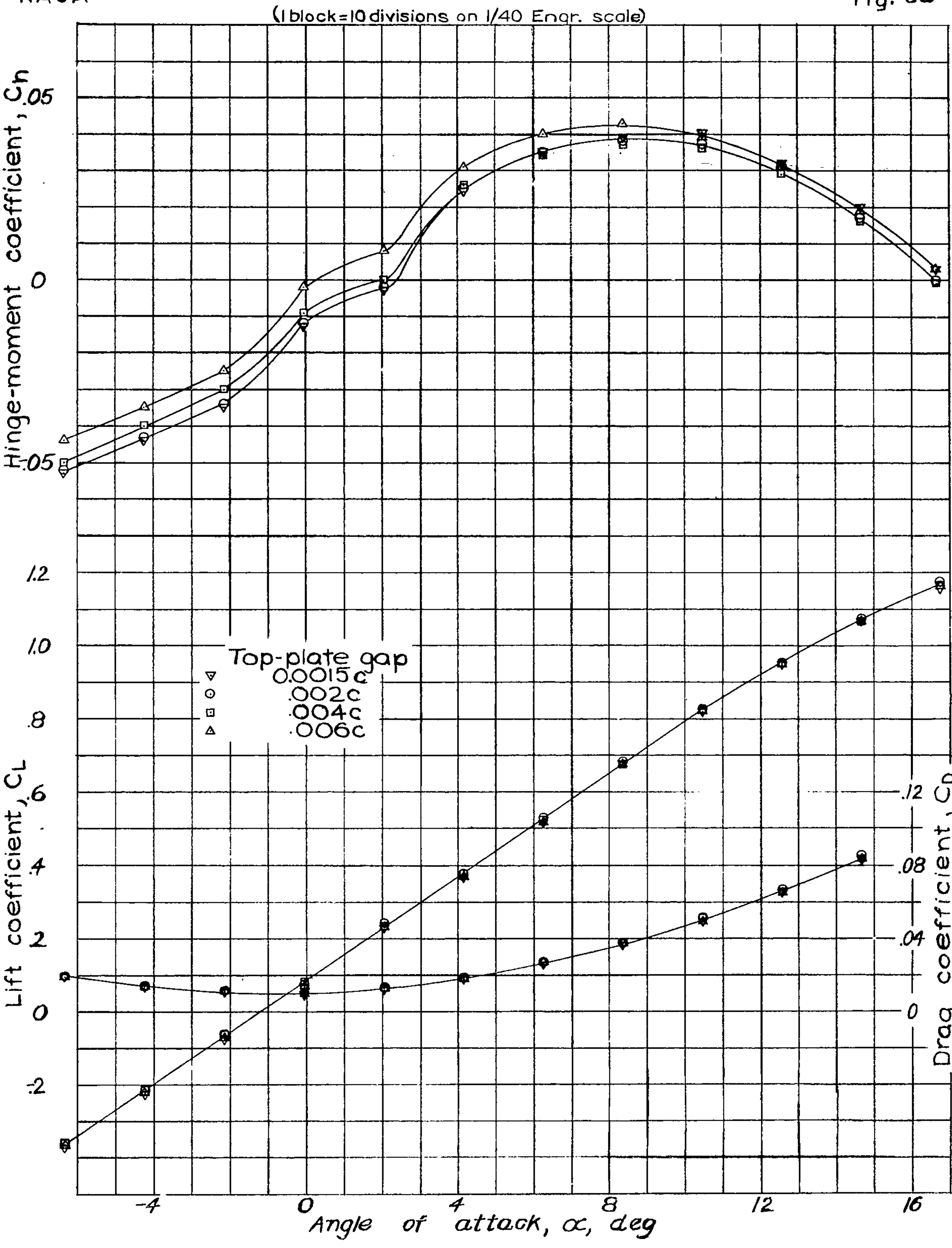


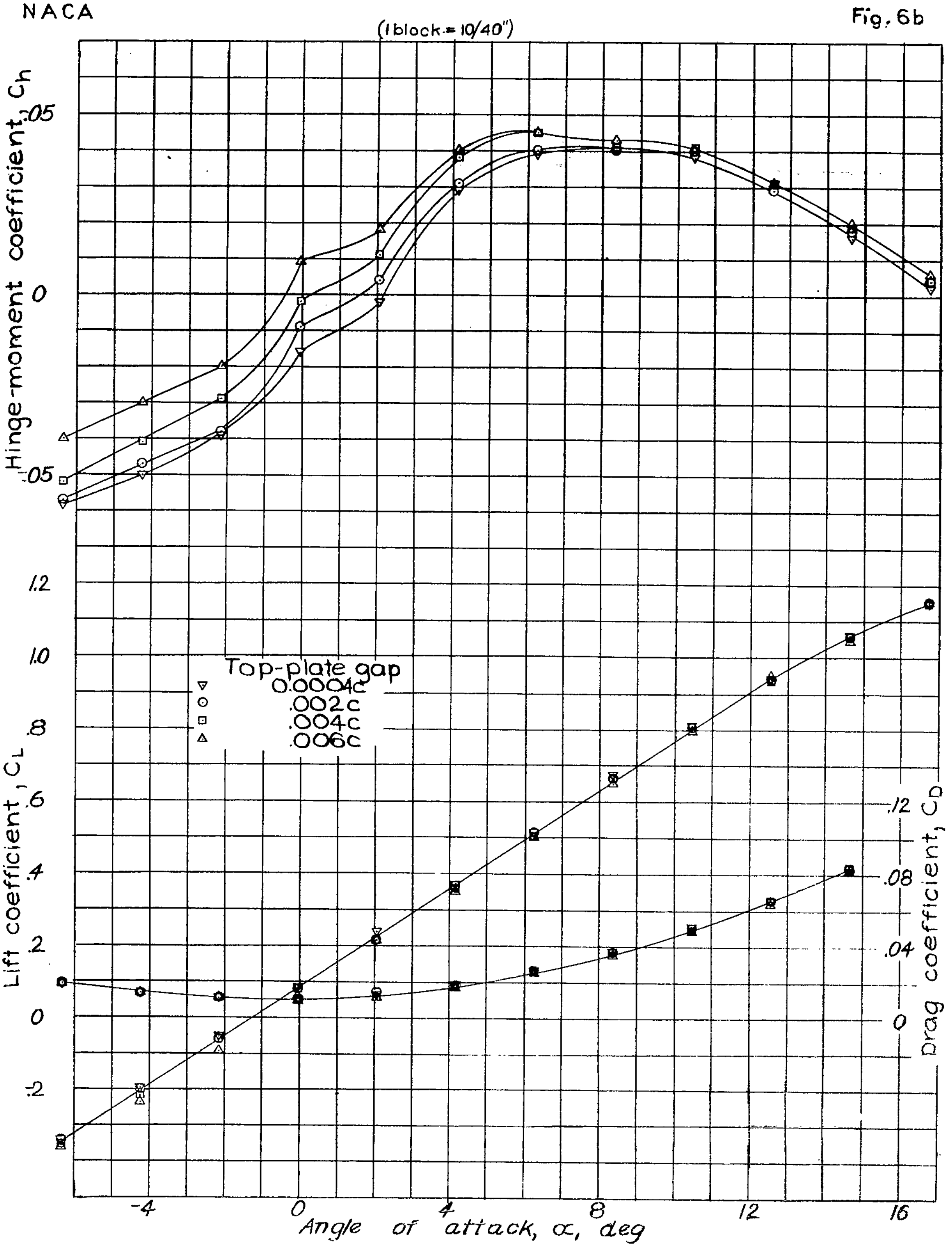
FIGURE 5 - Schematic diagram of test installation

Fig. 5



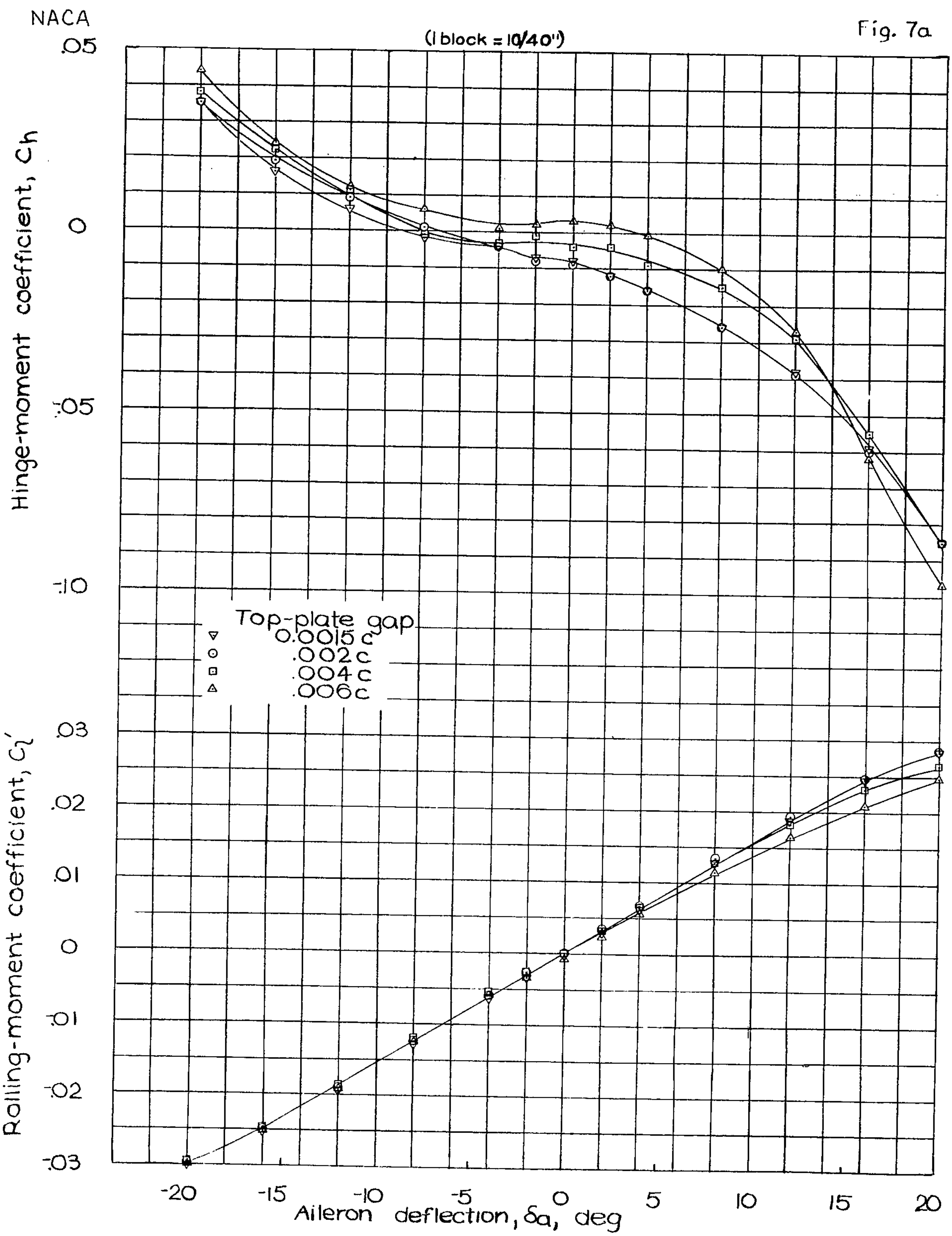
(a) Aileron gap sealed.

Figure 6.- The effect of alinement of top cover plate on the characteristics of the model with aileron and tab neutral. Tab gap sealed.



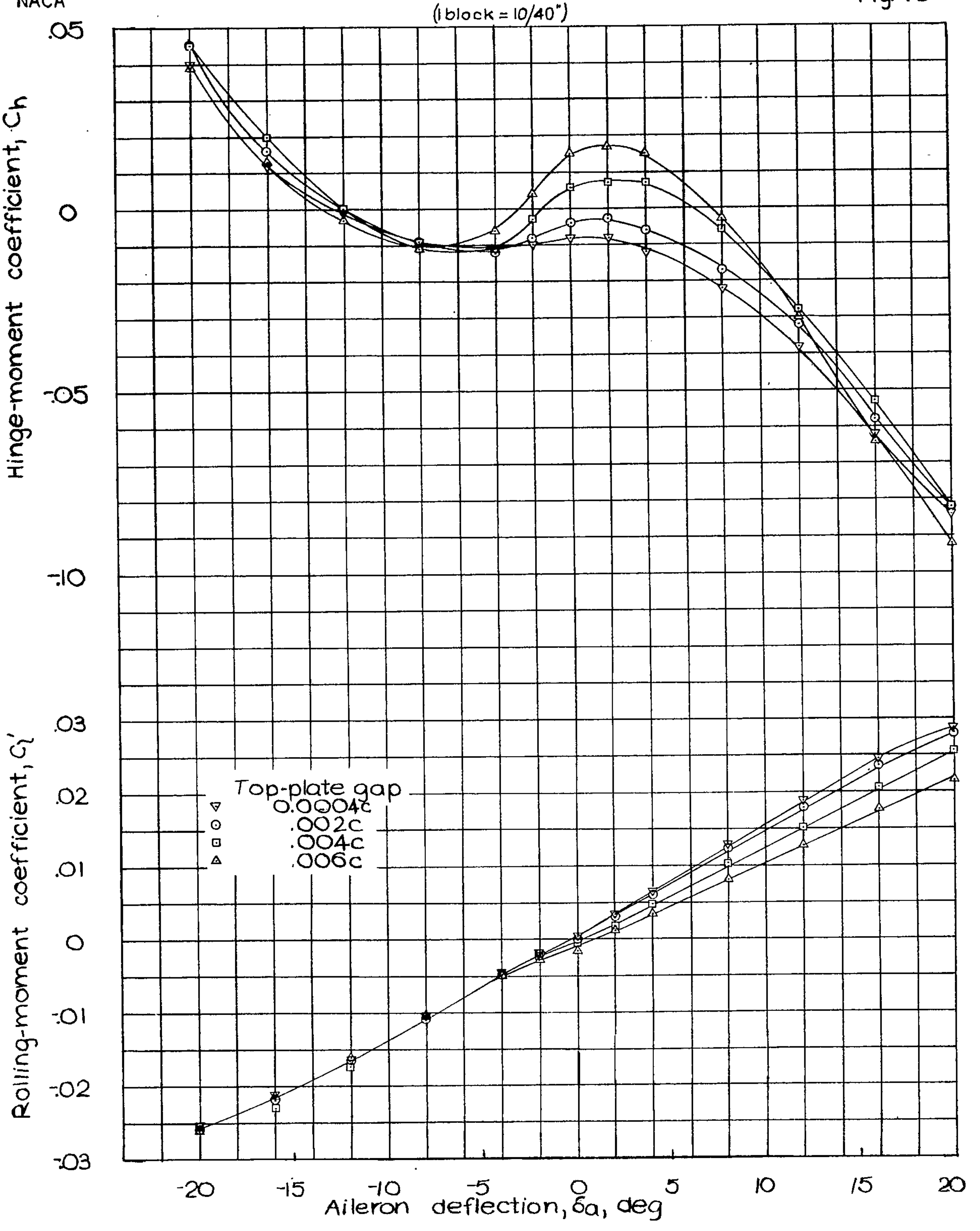
(b) Aileron gap, 0.002c.

Figure 6.- Concluded.



(a) Aileron gap sealed.

Figure 7.- The effect of alinement of top cover plate on the rolling- and the hinge-moment coefficients of the model. Tab gap sealed; α, 1.0°.



(b) Aileron gap, 0.002c.

Figure 7- Concluded.

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Fig. 8a,b

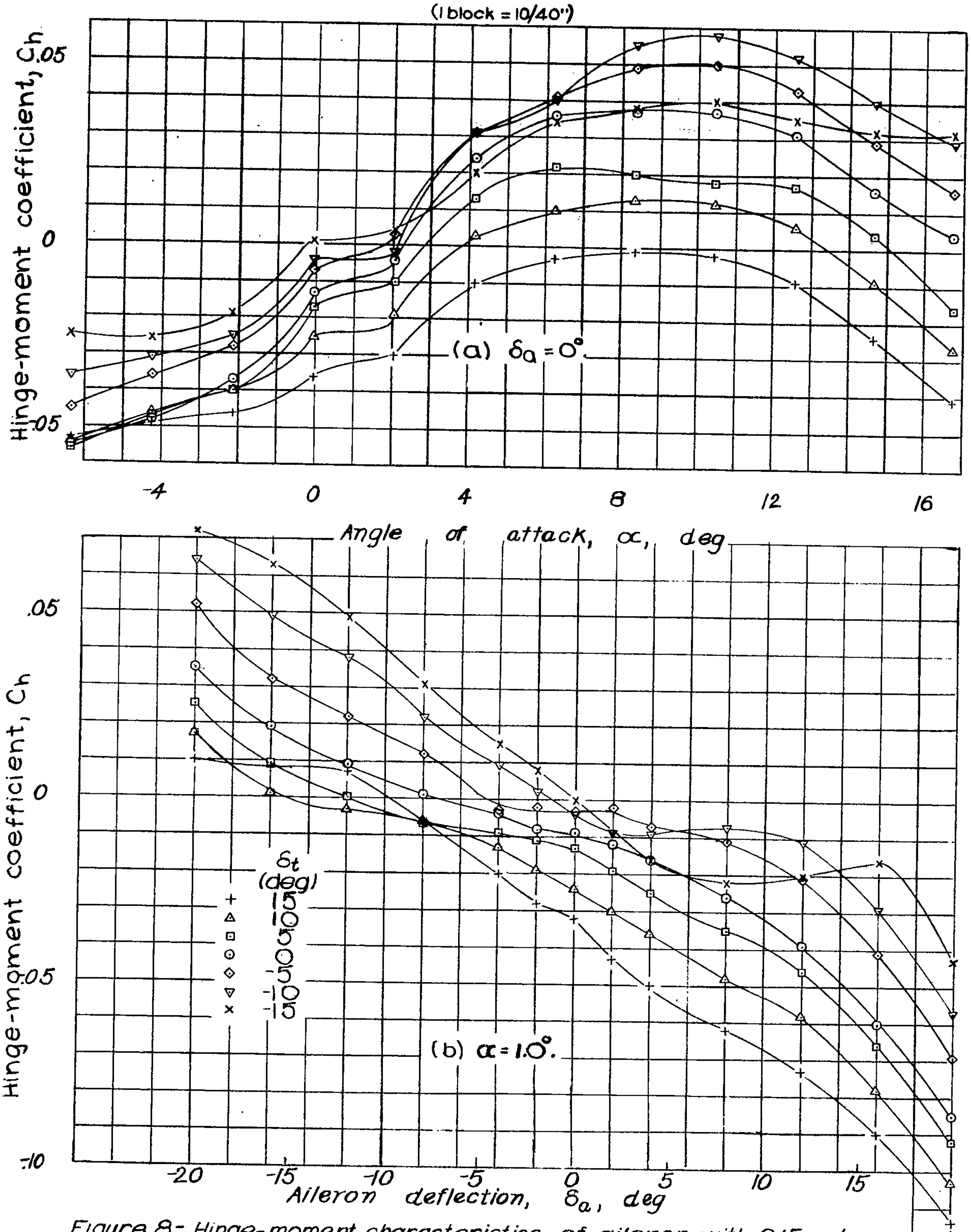


Figure 8.- Hinge-moment characteristics of aileron with $0.15c_a$ by $0.30b_a$ tab. Aileron and tab gaps sealed.

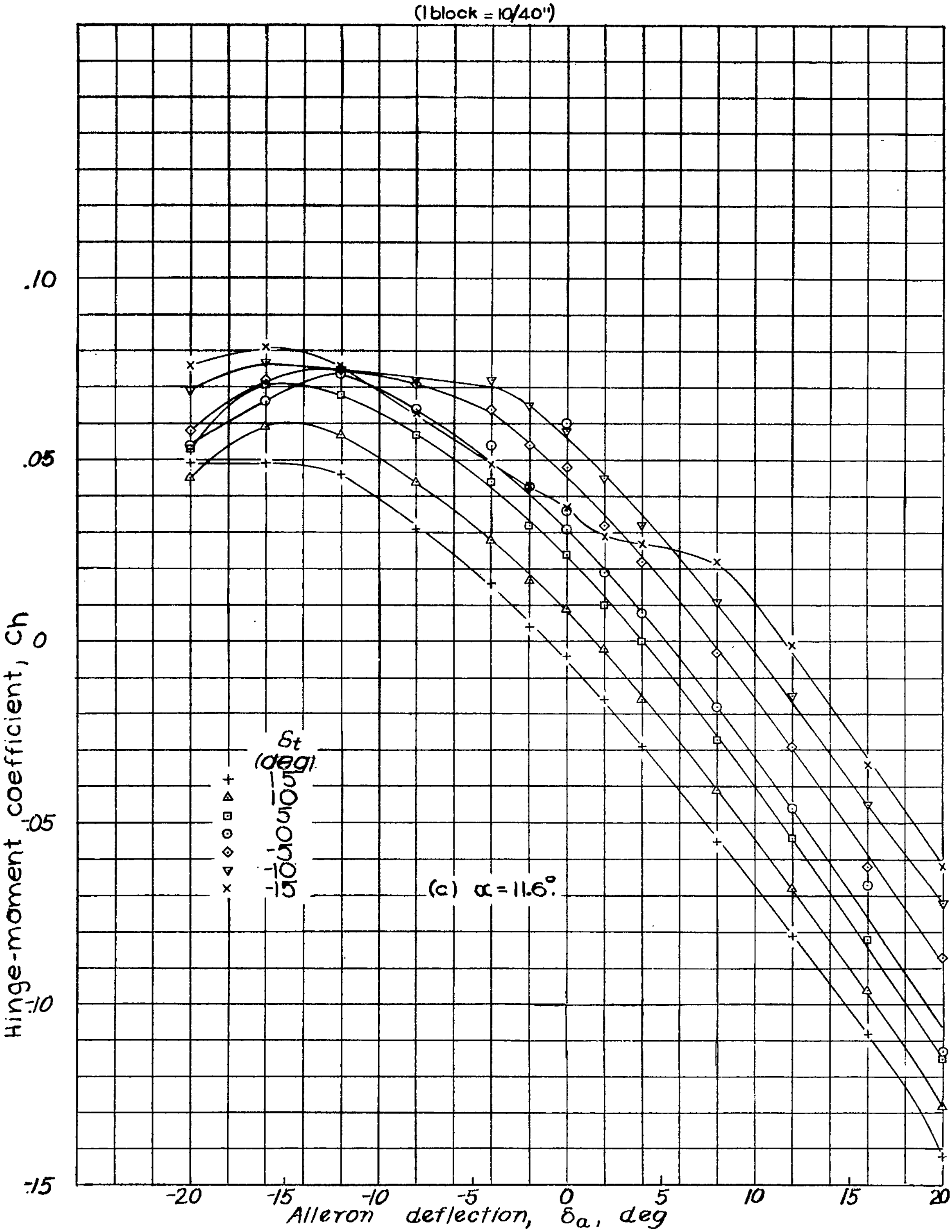
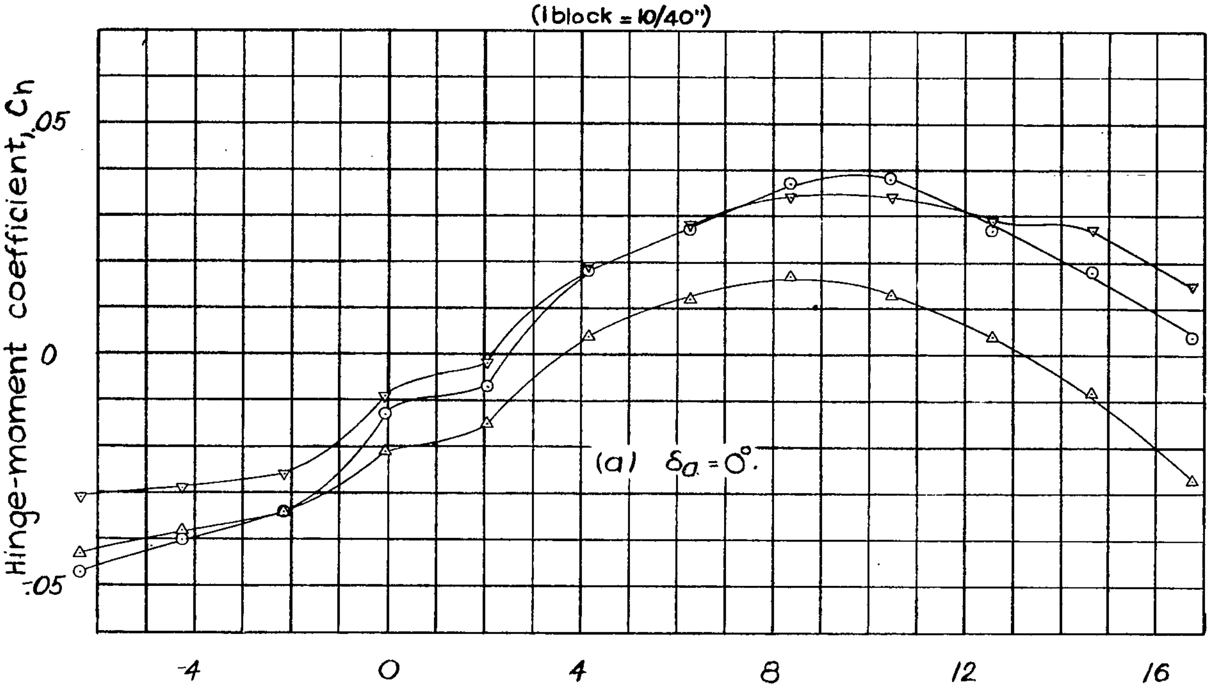


Figure 8.- Concluded.



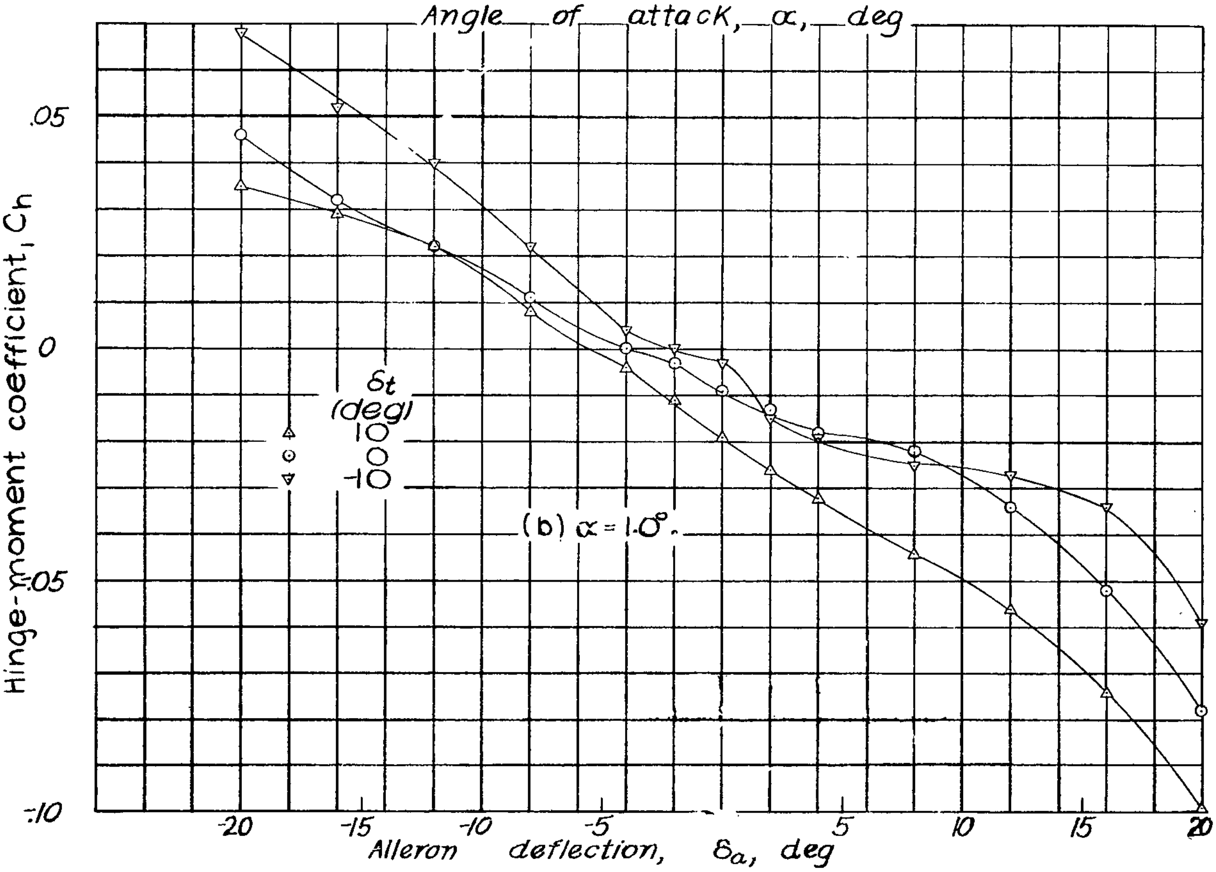


Figure 9.- Hinge-moment characteristics of aileron with 0.15 c_a by 0.30b_a tab. Aileron gap sealed; tab gap, 0.002c.

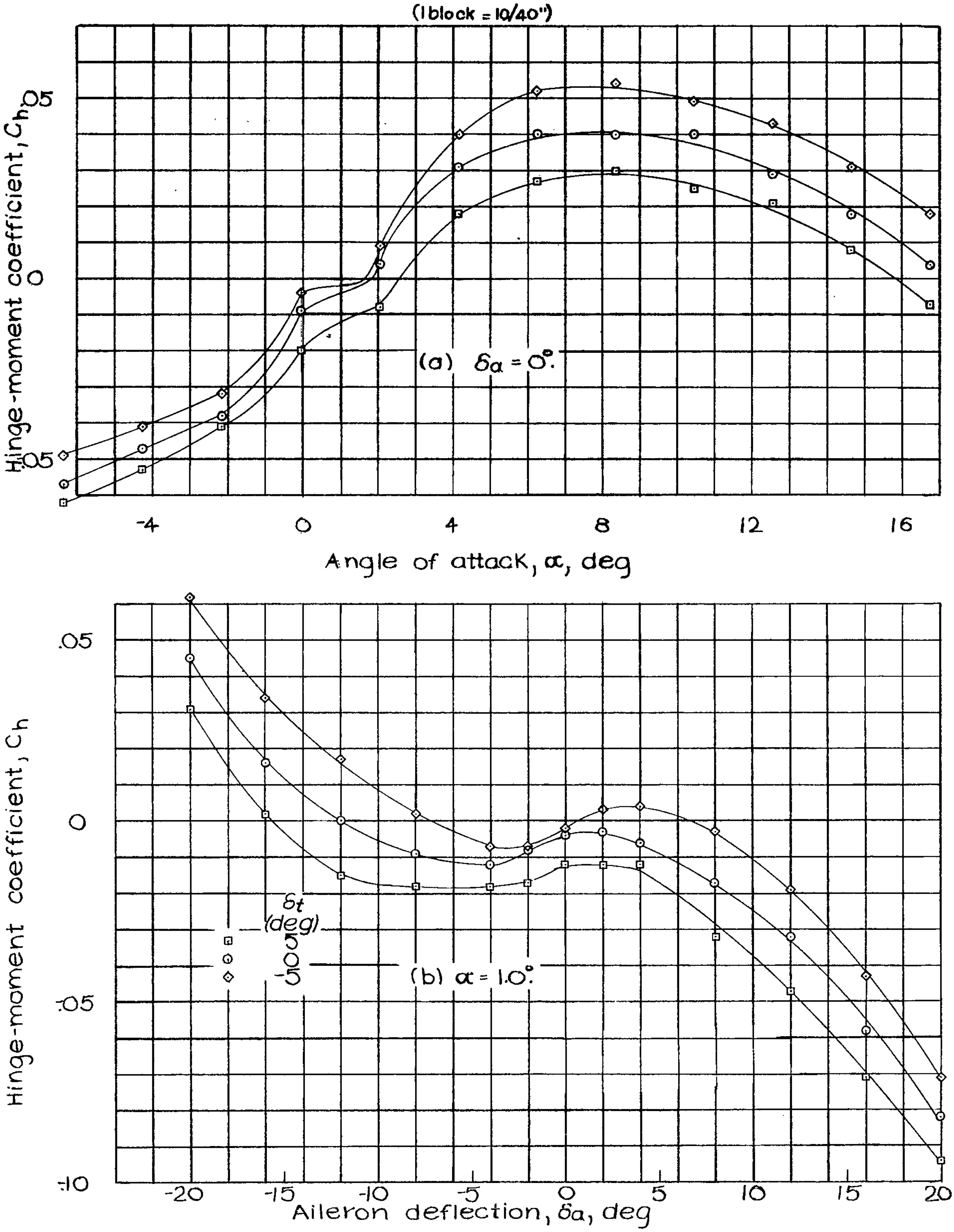
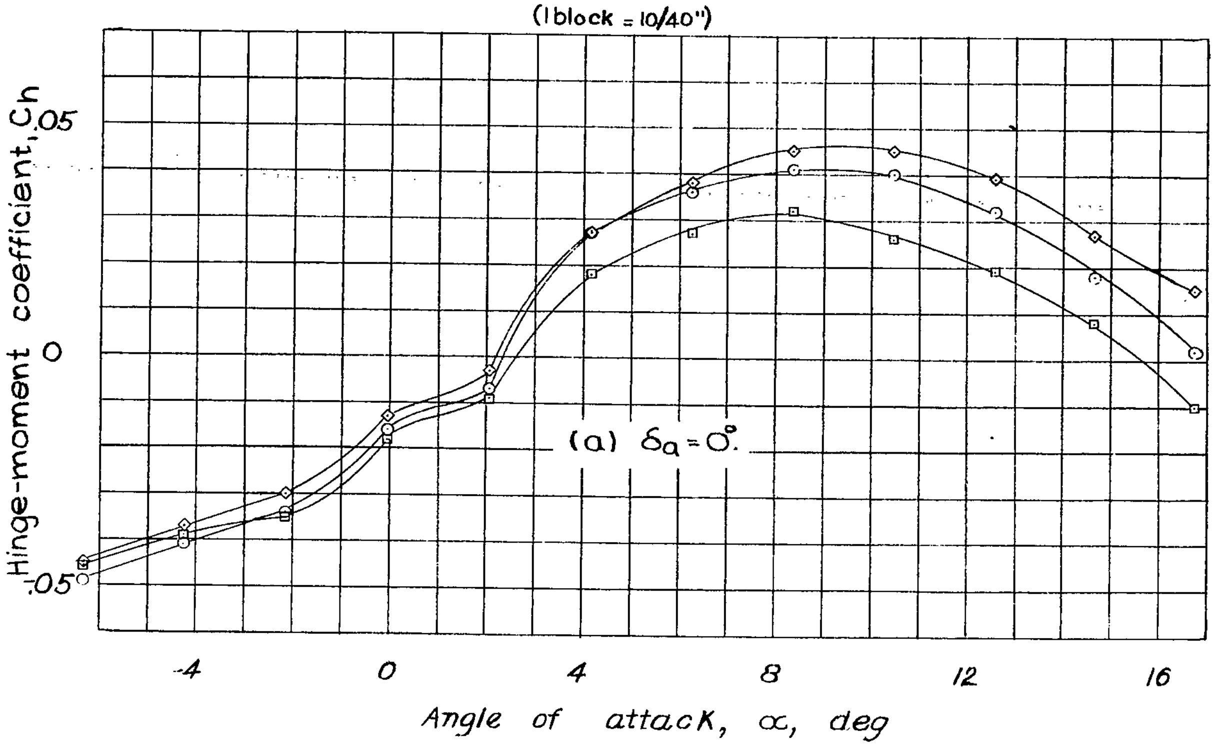


Figure 10.- Hinge-moment characteristics of aileron with 0.15 c_a by 0.30 b_a tab. Aileron gap, 0.002c; tab gap sealed.



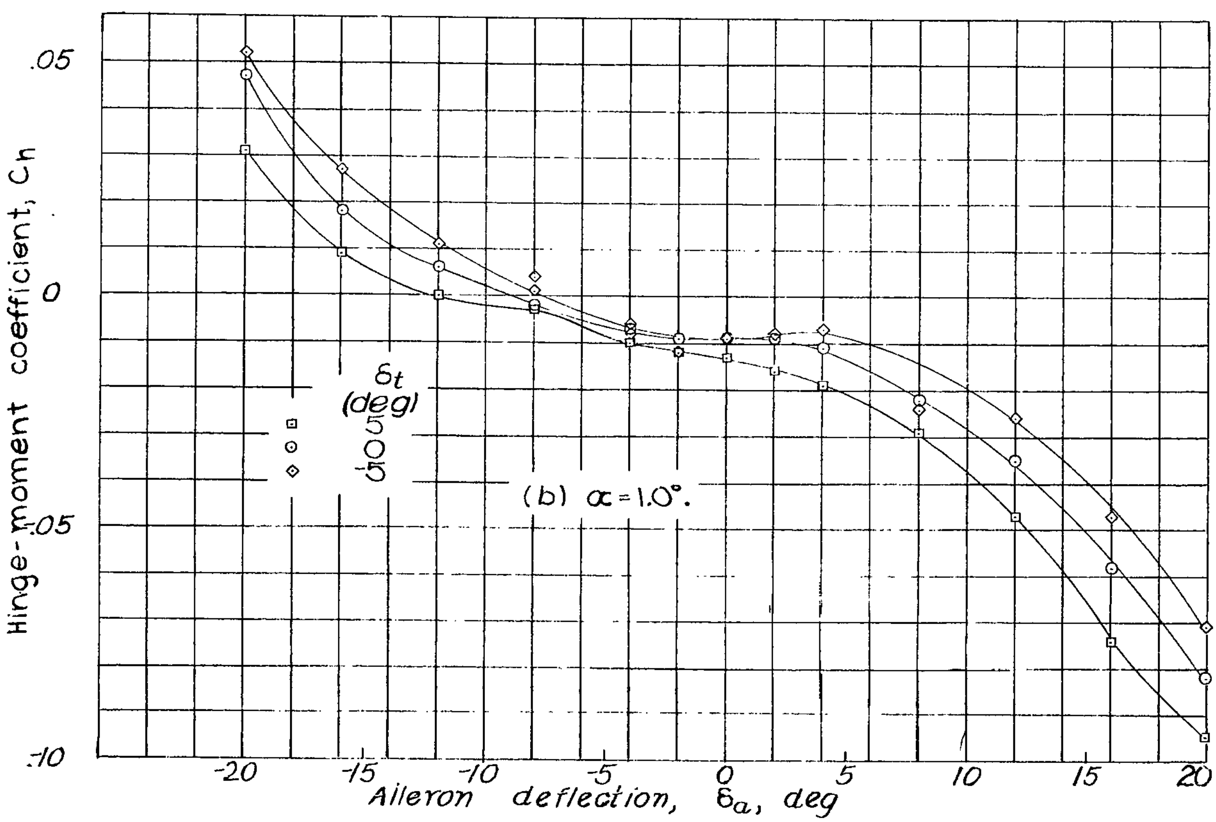


Figure 11.- Hinge-moment characteristics of aileron with $0.15c_a$ by $0.30b_a$ tab. Aileron gap, 0.002c; tab gap, 0.002c.

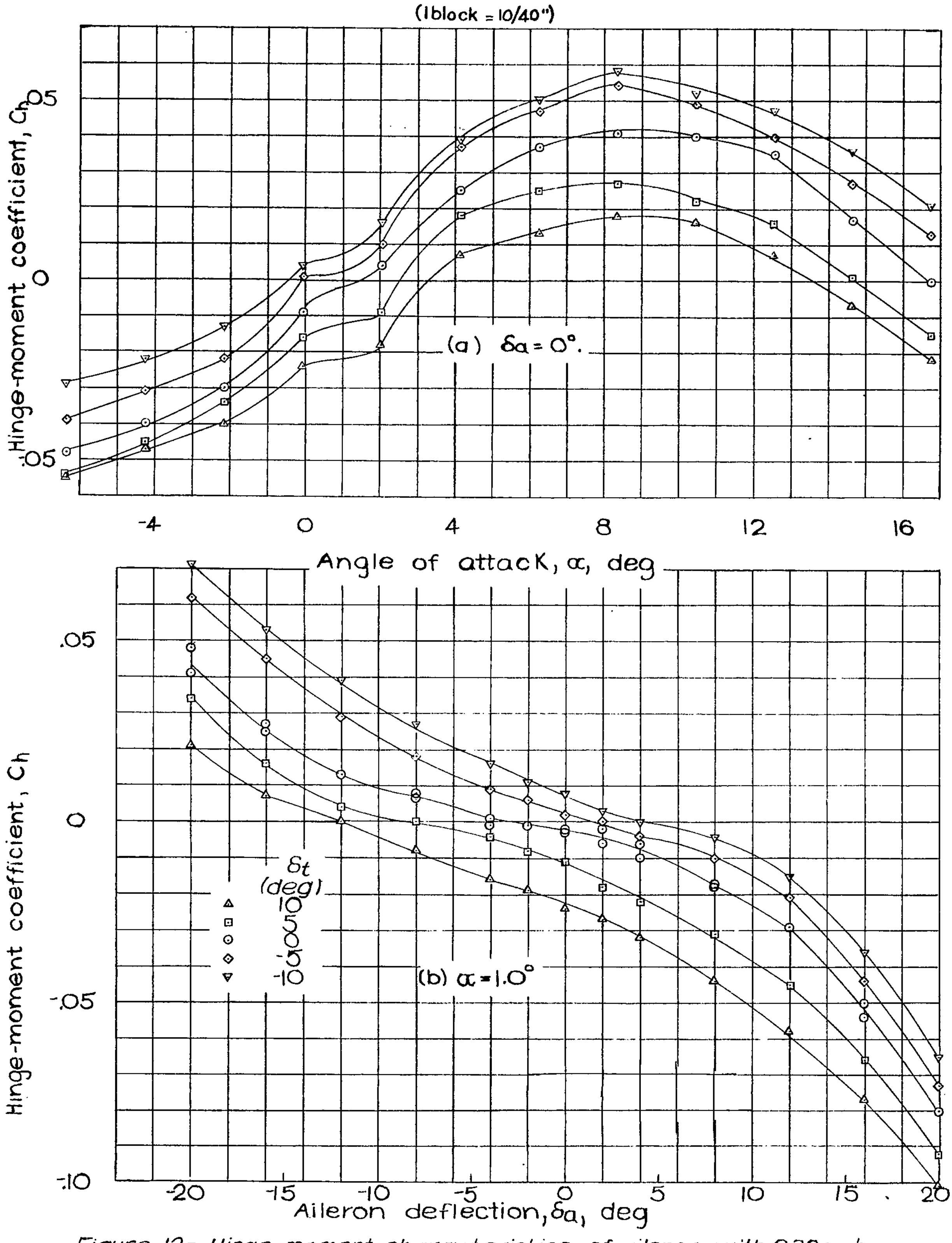


Figure 12.- Hinge-moment characteristics of aileron with 0.30c_a by 0.20b_a tab. Aileron and tab gaps sealed.

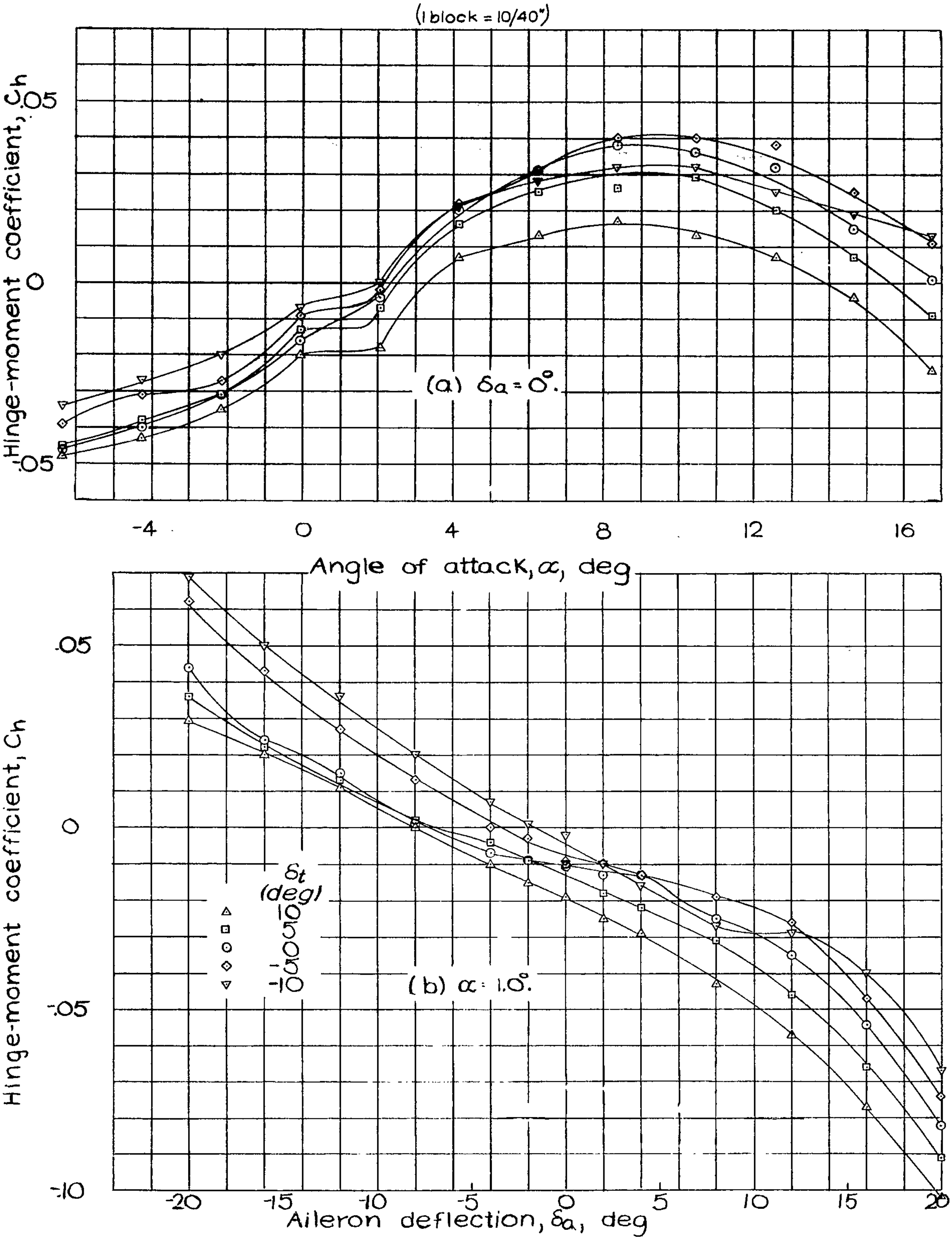
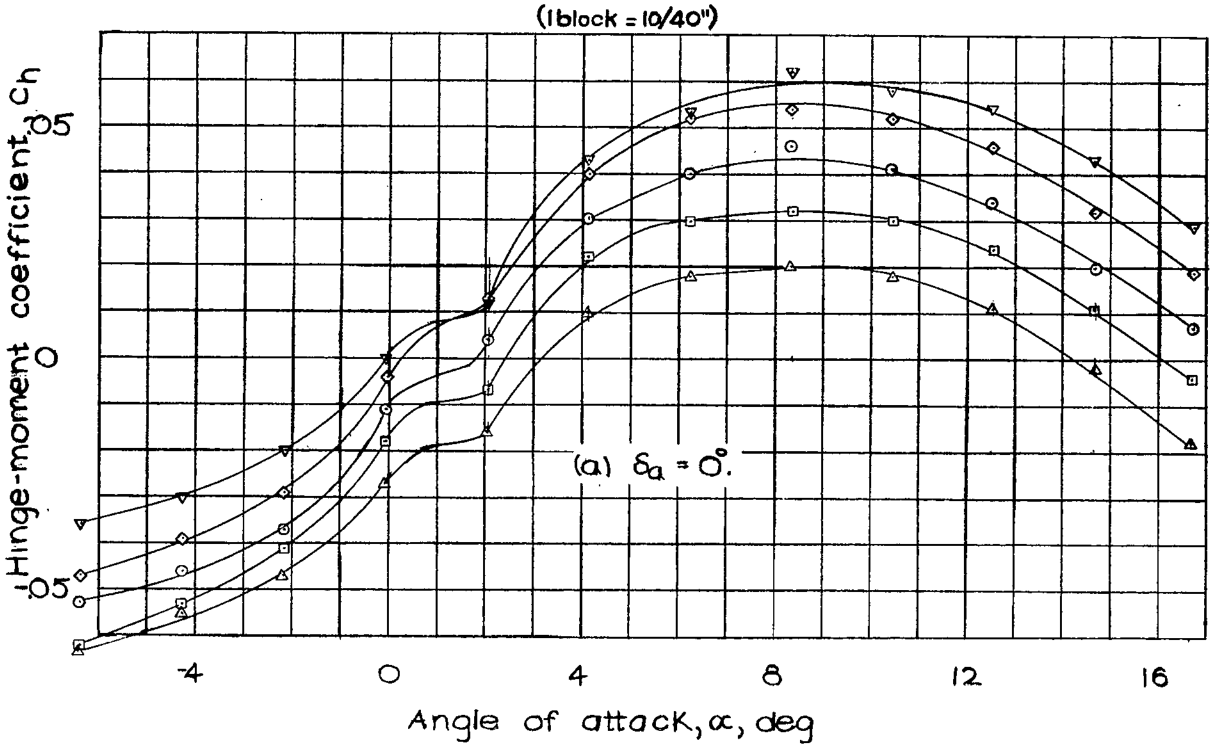


Figure 13.- Hinge-moment characteristics of aileron with $0.30c_a$ by $0.20b_a$ tab. Aileron gap sealed; tab gap, 0.002c.



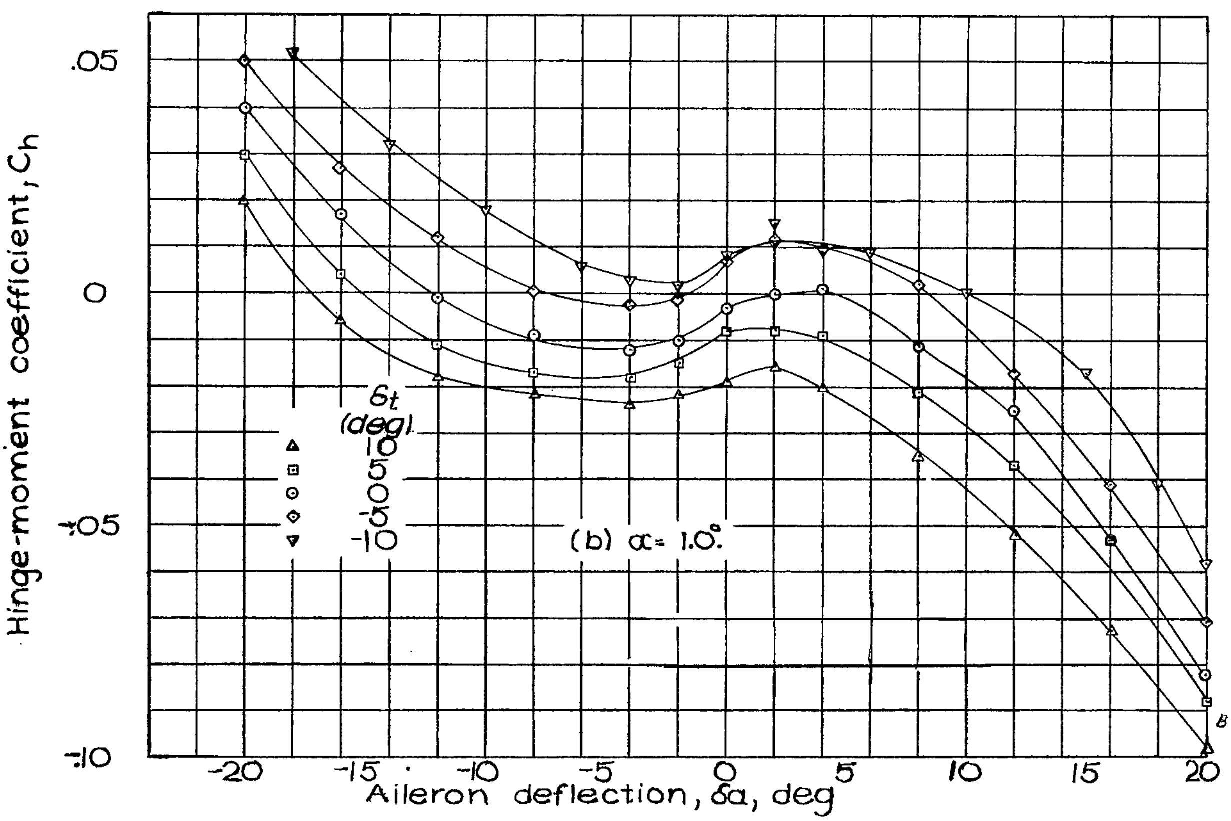


Figure 14.- Hinge-moment characteristics of aileron with 0.30c_a by 0.20b_a tab. Aileron gap, 0.002c; tab gap sealed.

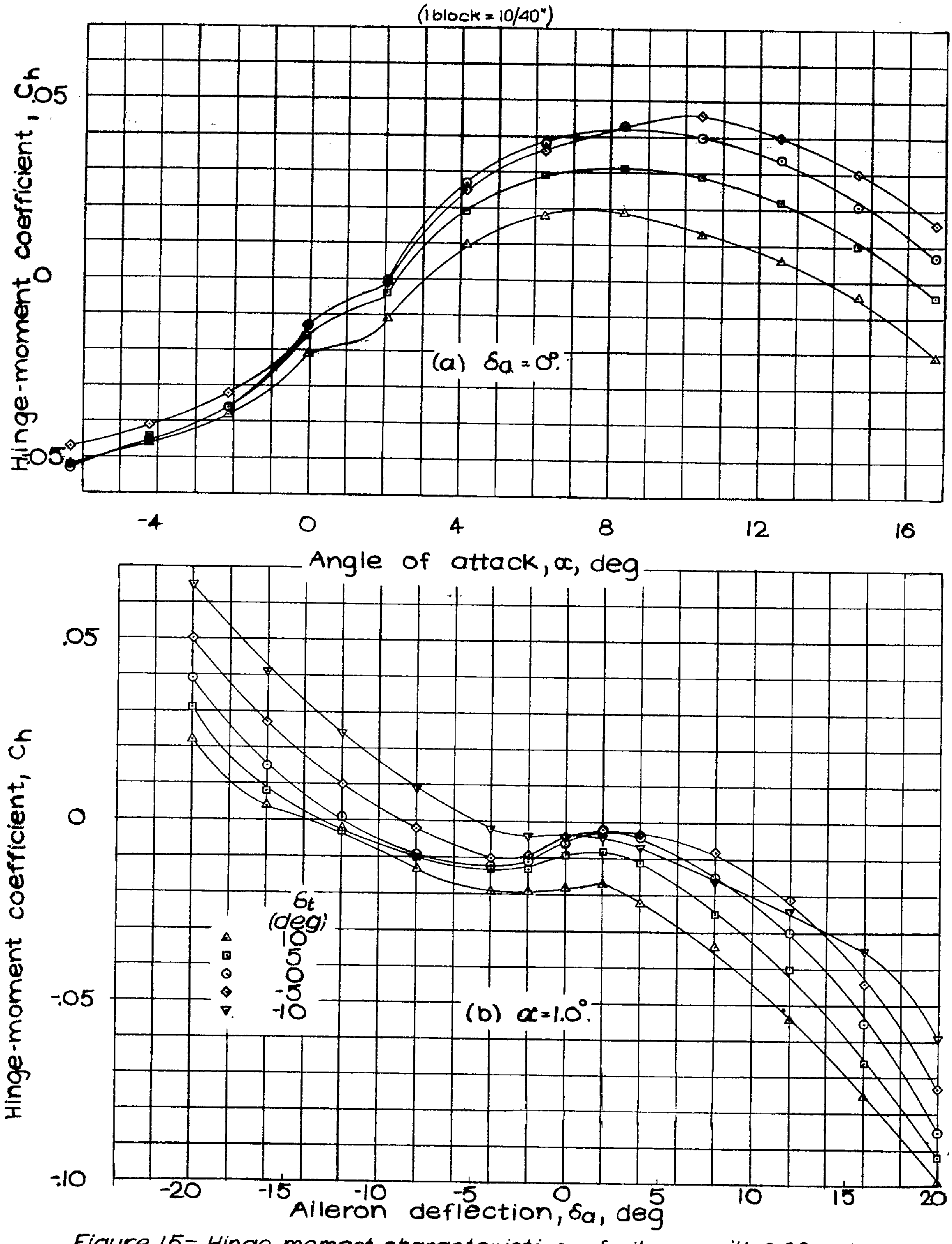


Figure 15.- Hinge-moment characteristics of aileron with 0.30 c_a by 0.20 b_a tab. Aileron gap, 0.002c; tab gap, 0.002c.

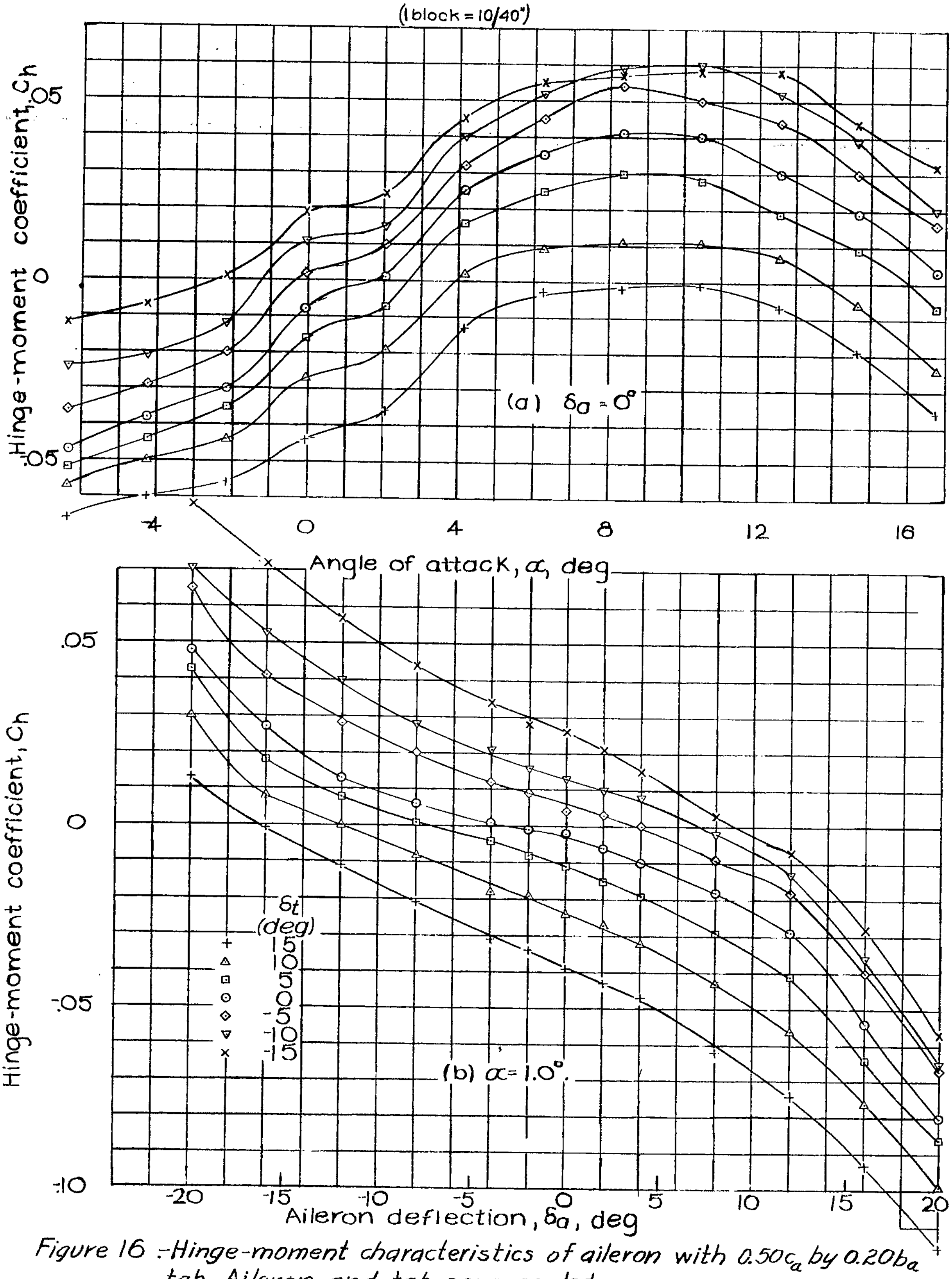


Figure 16 - Hinge-moment characteristics of aileron with $0.50c_a$ by $0.20b_a$ tab. Aileron and tab gaps sealed.

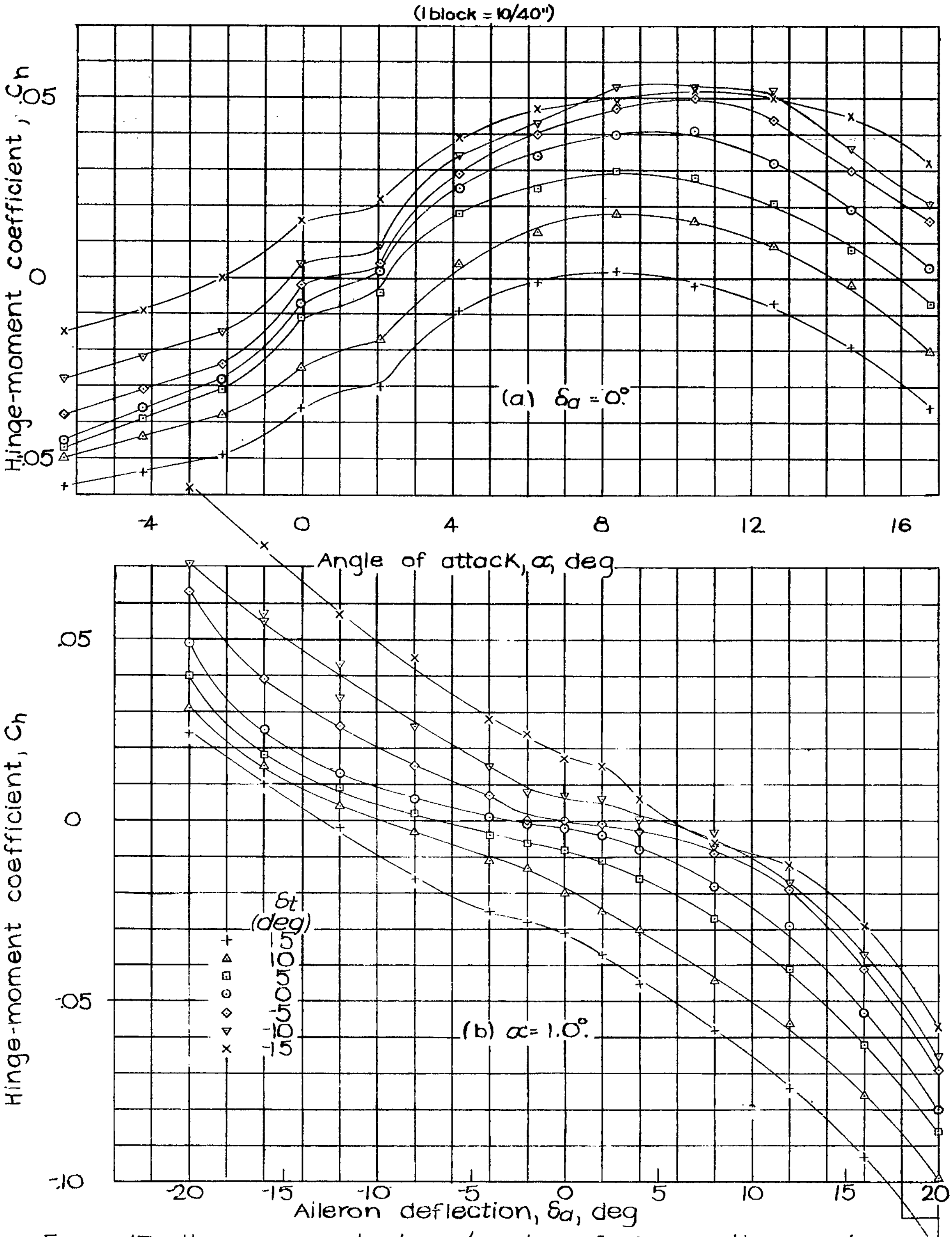


Figure 17.- Hinge-moment characteristics of aileron with 0.50 c_a by 0.20 b_a tab. Aileron gap sealed; tab gap, 0.002c.

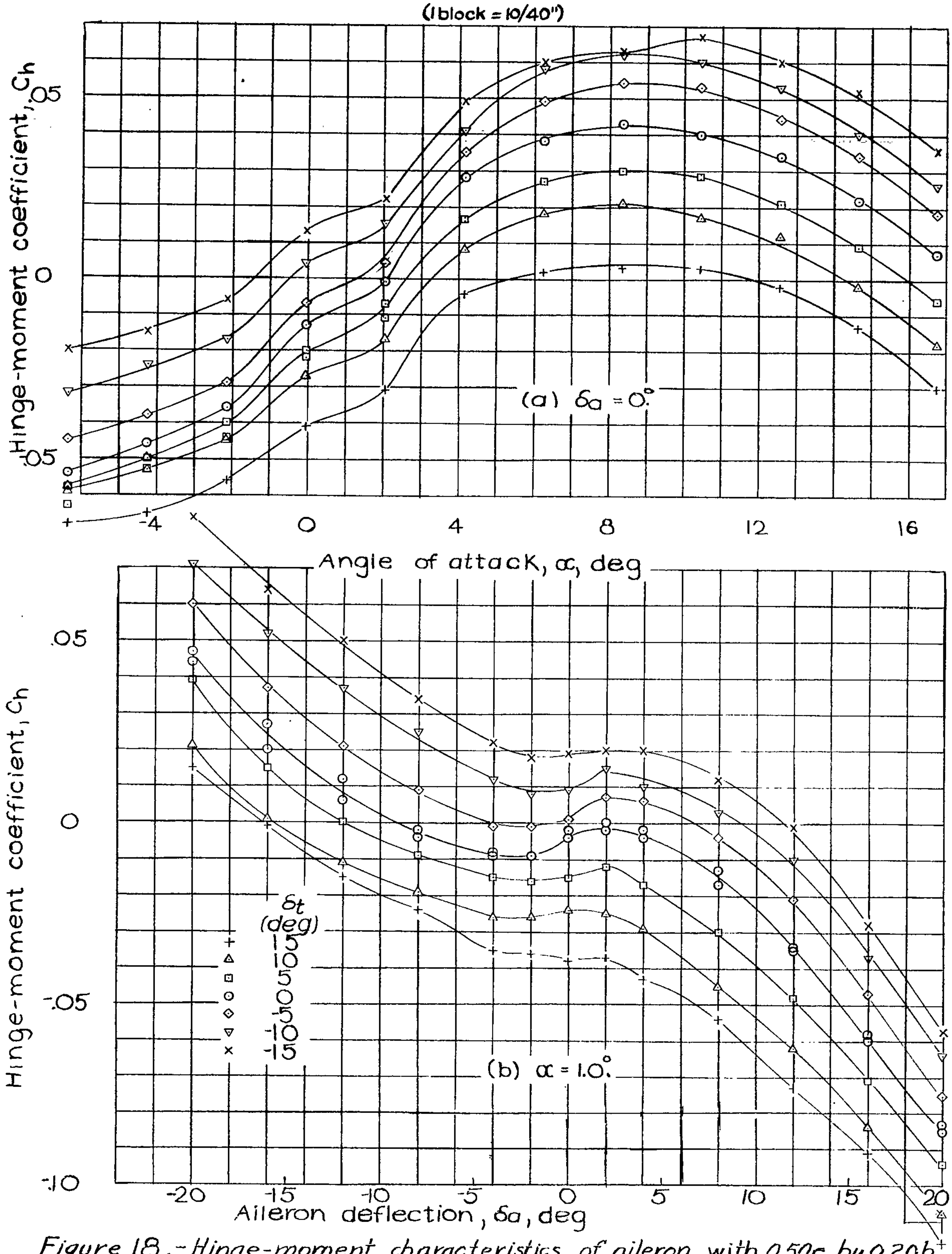


Figure 18.- Hinge-moment characteristics of aileron with $0.50c_a$ by $0.20b_a$ tab. Aileron gap, 0.002c; tab gap sealed.

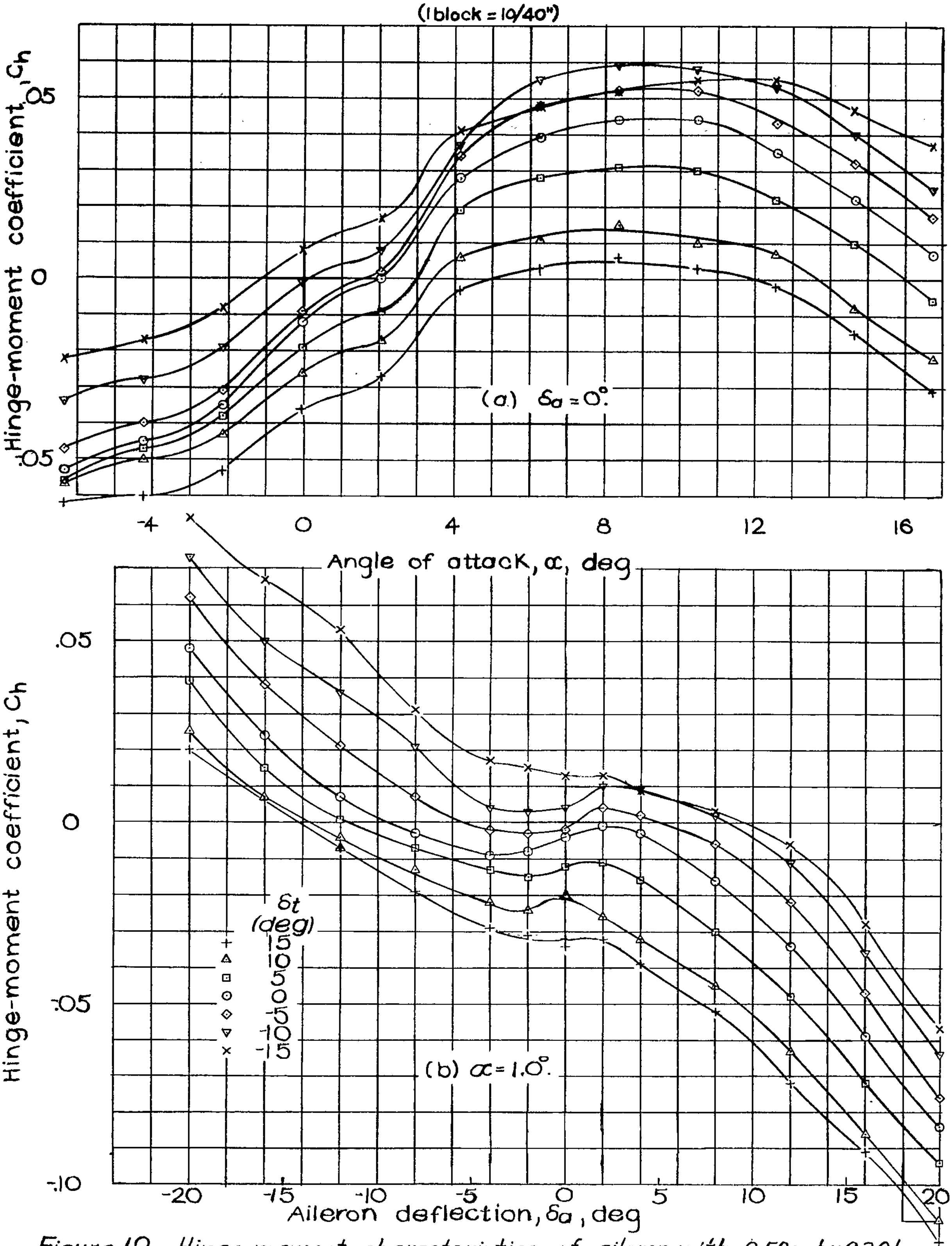


Figure 19.- Hinge-moment characteristics of aileron with $0.50c_a$ by $0.20b_a$ tab. Aileron gap, 0.002c; tab gap, 0.002c.

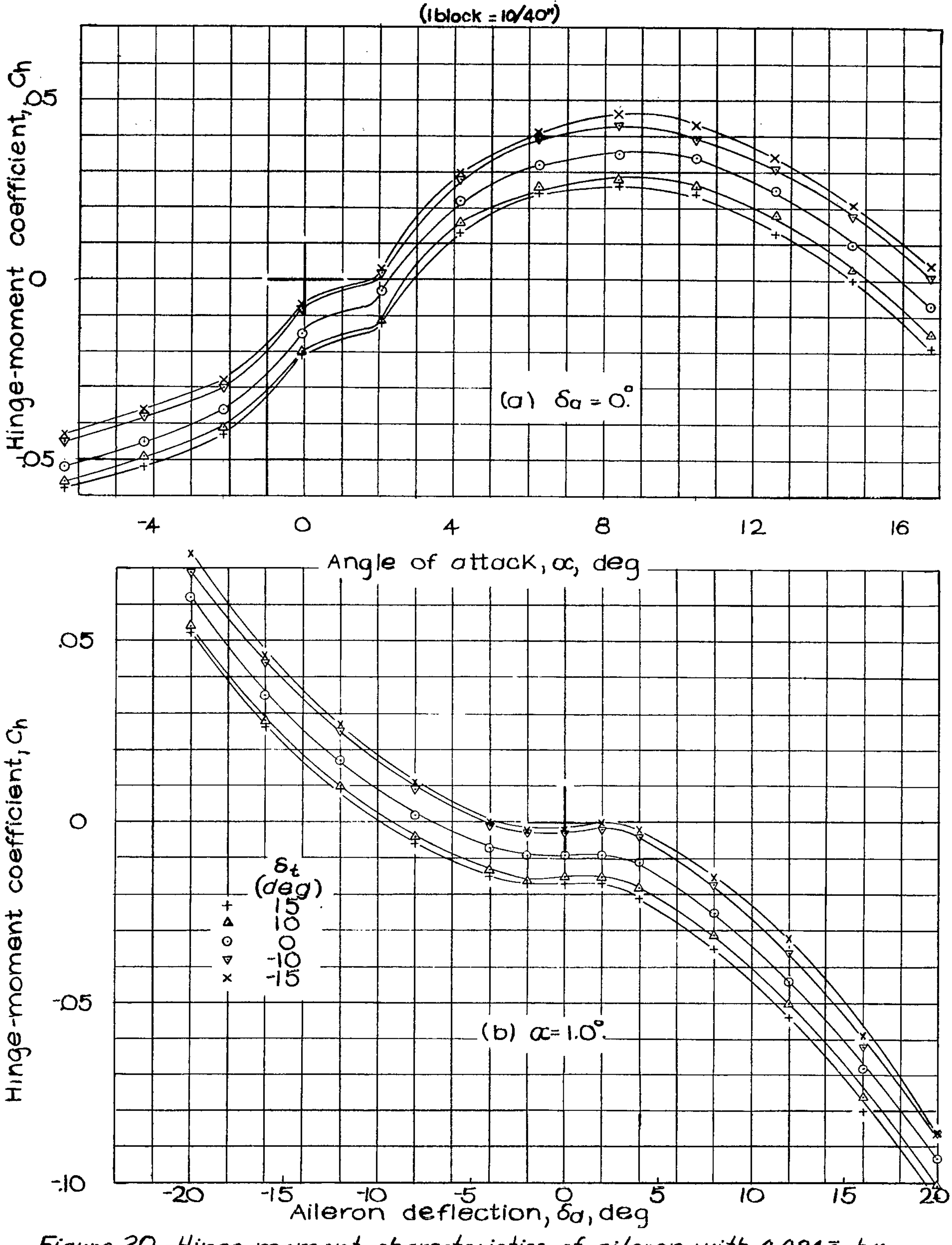


Figure 20.-Hinge-moment characteristics of aileron with $0.084\bar{c}_a$ by $0.126\, b_a$ attached tab. Aileron gap, 0.002c; tab gap sealed.